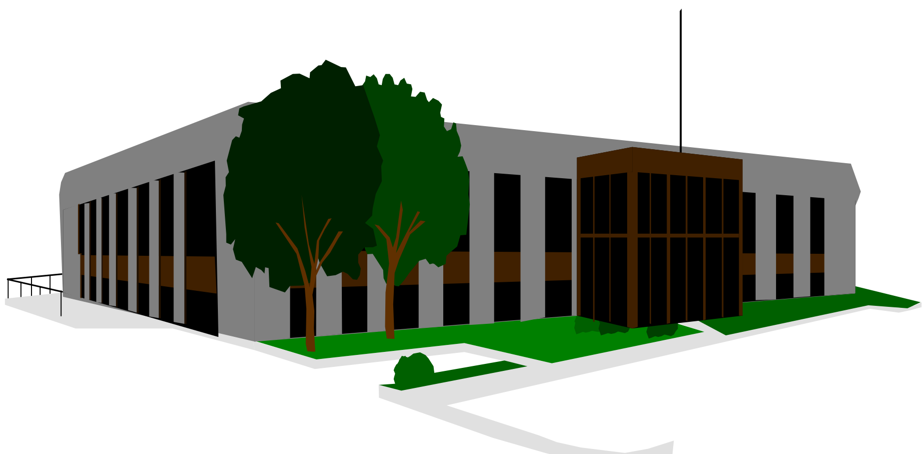
INDOOR AIR QUALITY ASSESSMENT

Holliston High School
370 Hollis Street
Holliston, Massachusetts



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March, 2001

Background/Introduction

At the request of several parents and the Holliston Board of Health, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at Holliston High School, 370 Hollis Street, Holliston, Massachusetts. Reports that the building had been evacuated due to elevated carbon monoxide levels in addition to concerns about pollutants generated by renovation efforts and their potential impact on classroom occupants prompted this request.

On December 21, 2000, Michael Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), examined the adequacy of measures taken to prevent pollutants from migrating from the area of renovation into occupied areas in the school. Mr. Feeney was accompanied by Michael Cassidy, Chief of the Holliston Fire Department, and at times by Ann McCobb, of the Holliston Board of Health. On December 22, 2000, Mr. Feeney returned to the school with Cory Holmes of BEHA to conduct further evaluation of renovation containment as well as general air monitoring in occupied areas of the building. Preliminary recommendations and other information concerning renovation generated pollutants were previously outlined in a letter (MDPH, 2001).

The school is a two-story red brick structure built in the 1960s. The school contains general classrooms, science classrooms, art room, computer lab, music room, a woodshop, gymnasium, locker rooms, library, cafeteria and office space. At the time of both inspections, a significant portion of the science wing, the auditorium, areas around the gymnasium and general classrooms along the two-story wing were all under renovation (see Figure I). Hallway entrances were sealed with a combination of temporary plywood wall and plastic sheets affixed with duct tape. The south side of the science wing was open to the outdoors and covered by a tarpaulin (see Picture 1).

The Holliston Fire Department has responded to a number of complaints related to these renovations (HFD, 2000a). As a result of measuring carbon monoxide in the building, the Holliston Fire Department ordered Peabody Construction to cease use of internal combustion engine-powered equipment during school hours (HFD, 2000b). Use of internal combustion engine-powered equipment during school hours was restarted on a trial basis under the condition that carbon monoxide levels measured in occupied areas not exceed 9 parts per million (ppm) (HFD, 2000c).

The contractor, Peabody Construction, hired two separate industrial hygiene consultants to assess the indoor air quality within the school. Since September 2000, indoor air quality measurements were taken during construction activities to measure airborne mold spores (UEC, 2000c), temperature (EHI, 2000a; EHI, 2000b; EHI, 2000c), relative humidity (EHI, 2000a; EHI, 2000b; EHI, 2000c), glass fibers (EHI, 2000a; EHI, 2000b), carbon monoxide (EHI, 2000a; EHI, 2000b; EHI, 2000c; UEC, 2000a; UEC, 2000b), carbon dioxide (EHI, 2000a; EHI, 2000b; EHI, 2000c; UEC, 2000a; UEC, 2000b), airborne dust (EHI, 2000a; EHI, 2000b; EHI, 2000c; UEC, 2000a; UEC, 2000b) and total volatile organic compounds (TVOCs) (EHI, 2000a; EHI, 2000b; EHI, 2000c). All parameters tested by Environmental Health, Inc. were reportedly unremarkable and well below allowable criteria for dust fibers, carbon monoxide and carbon dioxide. No recommendations were made in any of the three reports (EHI, 2000a; EHI, 2000b; EHI, 2000c). Air tests taken by Universal Engineer Corp. indicated inadequate ventilation in occupied areas of the building based on carbon dioxide measurements (UEC, 2000a;

UEC, 2000b). The Universal Engineer Corp. report on airborne mold testing indicated total airborne mold concentrations in the building measured between 3.7 and 8.5 times lower than the outside sample and that no individual molds of specific concern were identified UEC, 2000c).

Notable in each of these consultant reports are the use of either Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and American Conference of Governmental Industrial Hygienist (ACGIH) Threshold Limit Values (TLVs) as comparison values for carbon monoxide and airborne dust air monitoring results. Both PELs and TLVs are designed for occupational exposure of healthy adults. While these occupational exposure standards are commonly used in an industry setting, they are not appropriate for use in a building with children or adults with compromised health.

Methods

Air tests conducted by the MDPH for carbon dioxide, carbon monoxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). Air monitoring for airborne particulate was conducted with a TSI, P-Trak™ Ultrafine Particle Counter (UPC) Model 8525.

Results

This school has a student population of approximately 1,100 and a staff of approximately 100. The tests were taken during normal operations at the school. Test results appear in Tables 1-4.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in thirty-one of thirty-four areas surveyed. These levels are indicative of an overall ventilation problem in the school. It is also noted that several classrooms were sparsely populated and/or had open windows during the assessment, which can greatly contribute to reduced carbon dioxide levels. Of note was classroom 101 which had a carbon dioxide level approaching 3,000 ppm (2,956) carbon dioxide, indicating little or no air movement.

Fresh air in classrooms is supplied by a unit ventilator (univent) system (see Picture 2). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building (or in some cases on the roof (see Pictures 3 & 4)) and return air through an air intake located at the base of each unit (see Figure 2). Fresh air and return air are mixed, filtered, heated and provided to classrooms through a fresh air diffuser located in the top of the unit. Univents were deactivated in a number of classrooms surveyed (see Tables). Obstructions to airflow, such as books, papers and posters on top of univents, as well as bookcases, tables and desks in front of univent returns, were seen in a number of classrooms (see Pictures 2 & 5). To function as designed, univents and univent returns must remain free of obstructions. Importantly, these units must be activated and allowed to operate during hours of school occupation.

The mechanical exhaust ventilation system consists of either ceiling or wall-mounted exhaust vents (see Pictures 6 & 7) powered by rooftop motors or unit exhaust ventilators (see Picture 8) located along the exterior wall of the classroom. As with the univents, a number of exhaust vents were obstructed by tables, chairs, boxes and other items (see Picture 9). A number of unit exhaust ventilators were either off or drawing weakly. In addition several wall/ceiling vents were not operating, which can indicate that exhaust ventilation was turned off, or that rooftop motors were not functioning.

Classroom 100 contains a ceiling mounted exhaust vent but is not equipped with mechanical supply ventilation (shown in Picture 7). To introduce air into the room a passive vent was installed in the classroom door (see Picture 10). As air is drawn out of the room through the exhaust vent a negative pressure gradient is created, which facilitates the draw of air into the room through the passive vent. However, the exhaust vent was not operating, which rendered this system ineffective. Without removal by the exhaust ventilation, normally occurring environmental pollutants can build up (as evidenced by the elevated carbon dioxide levels) and lead to indoor air complaints.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing of these systems was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature readings ranged from 65^{o} F to 76^{o} F, which was below the BEHA recommended range in some areas. The BEHA recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is also difficult to control temperature and maintain comfort without operating the HVAC equipment as designed.

The relative humidity measured in the building ranged from 20 to 33 percent, which was below the BEHA recommended comfort range in all areas. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

A musty/moldy odor was detected in the library. BEHA staff identified a water damaged book on a shelving unit as the most likely source of these odors. The book was colonized with mold growth (see Picture 11). Some individuals can be sensitive to mold, which can result in irritation of the eyes, nose, throat or respiratory system. BEHA staff informed the librarian and recommended that the book be discarded.

Throughout the school, caulking around the interior and exterior windowpanes was crumbling, missing or damaged. Water damaged curtains were noted in Picture 12. Once mold has colonized, porous materials should be replaced, as they are difficult to clean. Repairs of window leaks are necessary to prevent further water penetration.

Repeated water damage can result in mold colonization of window frames, curtains and items stored on or near windowsills. Water damaged curtains in classrooms also appear old and disintegrating (see Picture 13). Particulate matter can be entrained and suspended in air by univents. Disintegrating textiles can be a source of particulates, which can be irritating to the eyes, nose and throat.

Stained ceiling tiles were observed in some areas (see Picture 14). Water-damaged ceiling tiles can provide a source of mold and mildew and should be replaced after a water leak is discovered. A few areas had plants (see Picture 15). Plant soil and drip pans can serve as source of mold growth. Plants should be properly maintained and be equipped with drip pans. Plants should also be located away from the air stream of mechanical ventilation to prevent aerosolization of dirt, pollen or mold.

Pooling water was observed in a number of areas on the roof (see Picture 16). The freezing and thawing of water during winter months can lead to roof leaks and subsequent water penetration into the interior of the building. Pooling water can also become stagnant, which can lead to mold and bacterial growth, which can be introduced into the building by rooftop fresh air intakes. In addition, stagnant pools of water can serve as a breeding ground for mosquitoes in warmer months.

Efficacy of Renovation Containment

The air monitoring results concerning the adequacy of containment of renovations are included as Appendix A (MDPH, 2001). This air testing consisted of monitoring for carbon monoxide and ultrafine particle concentrations in and around renovation areas adjacent to occupied areas of the school.

The use of fossil fuel-powered equipment (e.g., propane heaters, gasoline-powered forklifts, and acetylene welding) can produce carbon monoxide. Using carbon monoxide to detect sources of combustion pollutants has a major drawback. If the source of combustion pollutants is allowed to dilute in a large volume of air within a building, carbon monoxide concentrations may decrease below the detection limits of equipment. The process of combustion produces airborne liquids, solids and gases (NFPA, 1997). The measurement of airborne particulates, in combination with carbon monoxide measurements can be used to pinpoint the source of combustion products. Therefore measurements for ultrafine particles [particles measuring 0.02 micrometers (μm) to 1 μm in diameter] as well as carbon monoxide were conducted by BEHA staff.

The process of combustion produces a number of pollutants, depending on the composition of the material. In general, common combustion emissions can include carbon monoxide, carbon dioxide, water vapor and smoke. Of these materials, carbon monoxide can produce immediate, acute health effects upon exposure. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within the rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The US Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for exposure to carbon monoxide in outdoor air. Carbon monoxide levels in outdoor air must be maintained below 9 ppm over a twenty-four hour period in order to meet this standard (US EPA, 1999a). No carbon monoxide levels measured in the school exceeded the MDPH ice rink correction levels or NAAQS.

Construction activities (e.g., grinding, cutting, demolition) as well as the combustion of fossil fuels can produce particulate matter that is of a small diameter ($\leq$10 μm) which can penetrate into the lungs and subsequently cause irritation. For this reason a device that can measure particles of a diameter of 10 μm or less was used to identify pollutant pathways from construction sites into the occupied areas. Inhaled particles can cause irritation to the eyes, nose and respiratory tract.

BEHA air monitoring for airborne particulate was conducted with an UPC, which counts the number of particles that are suspended in a cubic centimeter (cm^3) of air. This type of air monitor is useful as a screening device, in that it can be used as to track the source of airborne pollutants by counting the actual number of airborne particles. The source of particles can be identified by moving the UPC through a building towards the highest measured concentration of airborne particles. Measured levels of particles/cm^3 of air increases as the UPC is moved closer to the source of particle production. While this equipment can ascertain whether unusual sources of ultrafine particles exist in a building or that particles are penetrating through containment barriers, it cannot be used to quantify whether the NAAQS PM_{10} standard was exceeded. The primary purpose of these tests at Holliston High School was to identify and reduce or prevent pollutant pathways.

The NAAQS for both carbon monoxide and airborne particles are used by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) as measures for assessing possible sources of indoor air quality pollutants in buildings (ASHRAE, 1989a). This standard states that the NAAQS for “acceptable contaminant levels in outdoor air…applies indoors for the same exposure times” (ASHRAE, 1989b). In addition, the Massachusetts Building Code also incorporates the NAAQS as standards for indoor air quality (SBBRS, 1997; BOCA 1993). The Building Officials & Code Administrators (BOCA) National Mechanical Code/1993 requires that measures be taken (e.g., air filtration or other means) to reduce outdoor particles in fresh air introduced into a building. This measure is intended to prevent the introduction of pollutants from outdoor sources into the indoor environment. The NAAQS are primary air standards (US EPA, 1999b), which are set "to protect the public health, including the health of 'sensitive' populations such as asthmatics, children and the elderly" (US EPA, 2000). If indoor air levels exceed the NAAQS for carbon monoxide and PM10, symptoms of respiratory irritation would be expected to occur in some sensitive individuals.

A comparison of outdoor concentrations to indoor concentrations of carbon monoxide and ultrafine particles was used to identify whether unusual sources of these pollutants exist indoors. At worst, indoor and outdoor levels for these pollutants would be expected to be equal. Filters installed within the building's HVAC system should reduce airborne concentration of suspended particles, which should result in ultrafine particle concentrations *lower* indoors than outdoors. Where indoor ultrafine particle concentrations are *higher* than outdoor levels; the most likely explanation would be from a point source inside the building.

Please note that indoor concentrations of carbon monoxide and ultrafine particles measured represent conditions present at the time of the BEHA assessment. Fluctuations above or below the measured concentration may have occurred. What is important to note is not the level of carbon monoxide within the school, but rather the presence of measurable levels in occupied areas where outdoor concentrations were non-detectable. The increase in concentrations of airborne ultrafine particulate in close proximity to areas under renovation, combined with the presence of carbon monoxide levels in occupied areas, indicate that containment measures employed at the time of the assessment need to be improved. The recommendations made in our previous correspondence should serve to prevent the migration of pollutants from renovation areas into occupied space and improve indoor air quality in the school.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. A number of containers including paint, waterproofing materials and other items were being stored on the floor in the storeroom off of class 151 (see Picture 17). These products contain VOCs, which readily evaporate and can be irritating to eyes, nose and throat. Some of these products are flammable as well, and should be stored in a cabinet which meets the criteria set forth by the National Fire Protection Association (NFPA) (NFPA, 1996).

Accumulated chalk dust was noted in several classrooms (see Picture 18). Chalk dust is a fine particulate, which can become easily aerosolized and serve as a source of eye and respiratory irritation. A number of classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs), (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999), which can also be irritating to sensitive individuals.

Several areas had missing/dislodged ceiling tiles (Picture 19). Missing ceiling tiles can provide a means of egress for odors, fumes, dusts and vapors between rooms and floors. Window-mounted air conditioners without covers were noted in rooms 100 & 203. The inside grills of the units were coated with dirt/dust (see Picture 20). The activation of this unit or the movement of ceiling tiles can introduce dirt, dust and particulate matter into occupied areas of the school. These materials can be irritating to certain individuals. In addition, air conditioners are normally equipped with filters, which should be cleaned or changed as per the manufacturer's instructions to avoid the build up and re-aerosolization of dirt, dust and particulate matter.

Finally, The following is a list of conditions of improperly stored materials that were found in the science wing:

- Bases were being stored in an acid storage cabinet along with acids. Bases and acids should not be stored together.
- Gas cylinders were stored in an upright position secured with clear packing tape (see Pictures 21 & 22). Cylinders of compressed gas should be fixed to a wall or stand to prevent damage to the cylinder valves by tipping. A damaged cylinder valve can cause an immediate and uncontrolled release of the cylinder contents and may result in the cylinder becoming a projectile.
- A number of materials appear to be of extreme age.
- Some containers were sealed with glass stoppers.
- Science classrooms contained inoperative ventilation hoods. Stored in these vent hoods were a number of different chemicals including a gas cylinder of chlorine (see Picture 23). Metal fixtures within the vent hood are corroded, which indicates that chemical vapors have escaped from the chemical hood at some previous date to corrode the exterior of this equipment. The purpose of chemical

hoods is to draw aerosolized chemical vapors and odors from the work area out of the building. Chemical hoods should not be used for storage of unattended materials because this equipment can be deactivated during off-hours (Rose, S. L., 1984). If the chemical hood is deactivated, off-gassing material can penetrate into adjacent areas. Chemical hoods should be on at all times that chemicals are within the equipment. It is also good chemical hygiene practice to return stock bottles back to the storage cabinet after use.

It is recommended that an ongoing, periodic inventory of chemicals in the science department be done to assess chemical storage and dispose of unwanted chemicals. Disposal of unwanted chemicals in a manner consistent with Massachusetts hazardous waste laws is recommended.

Conclusions/Recommendations

The conditions noted at Holliston High School raise a number of issues. The combination of the building design, maintenance, on-going renovations and the condition of stored materials if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to negatively affect indoor air quality in the building. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts require alteration to the building structure and equipment, which should be addressed during renovations. For these reasons a two-phase approach is required, consisting of more immediate **(short-term)** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns. In view of the findings at the time of this visit, the following recommendations are made:

The following **short-term** measures should be considered for immediate implementation:

1. Implement the corrective actions recommended concerning renovations in the building (MDPH, 2001).
2. To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy independent of thermostat control.
3. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers building-wide.
4. Examine rooftop exhaust motors and unit exhaust ventilators in classrooms for proper function and repair as necessary.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a HEPA filter equipped vacuum cleaner in conjunction with wet wiping of all non-porous surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

6. Remove moldy materials from the library and clean nonporous surfaces with an appropriate antimicrobial agent; wipe down afterwards with soap and water.
7. Keep plants away from univents in classrooms. Ensure plants have drip pans, examine drip pans for mold growth and disinfect areas with an appropriate antimicrobial where necessary.
8. Replace any remaining water-stained ceiling tiles, wall board and pipe insulation. Examine the areas above and around these areas for mold growth. Repair water leaks and disinfect areas of water leakage with an appropriate antimicrobial if necessary.
9. Replace water damaged/deteriorating curtains in classrooms.
10. Properly store chemicals and cleaning products. Have a chemical inventory done in all storage areas and classrooms. Discard hazardous materials or empty containers of hazardous materials in a manner consistent with environmental statutes and regulations. Follow proper procedures for storing and securing hazardous materials. Obtain Material Safety Data Sheets (MSDS') for chemicals from manufacturers or suppliers.
11. Maintain these MSDS' and train individuals in the science department in the proper use, storage and protective measures for each material in a manner consistent with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).
12. Seal utility holes and replace missing ceiling tiles to prevent egress of odors, fumes and vapors between rooms and floors.

13. Clean chalk boards and chalk trays regularly to prevent the build-up of excessive chalk dust.

14. Clean/change filters in window-mounted air conditioners as per the manufacturer's instructions to prevent the re-aerosolization of dirt, dust and particulate matter.

The following **long-term measures** should be considered:

1. Inspect roof for proper drainage and make repairs as needed, examine periodically for standing water.
2. Repair/replace broken and/or loose windows and replace missing or damaged window caulking to prevent water penetration through window frames.
3. Consider the installation of mechanical supply ventilation to classroom 100.

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Picture 1

Tarpaulin Covering South Side of Science Wing

Picture 2

Classroom Univent Note Materials on Air Diffuser Obstruction Airflow

Picture 3

Univent Fresh Air Intake

Picture 4

Univent Air Intake (Outside Window on Roof)

Picture 5

Univent Obstructed by Items on and in front of Unit

Picture 6

Wall-Mounted Exhaust Vent

Picture 7

Ceiling Mounted Exhaust Vent

Picture 8

Unit Exhaust Ventilator

Picture 9

Exhaust Vent Blocked by Boxes

Picture 10

Passive Vent Installed in Classroom 100

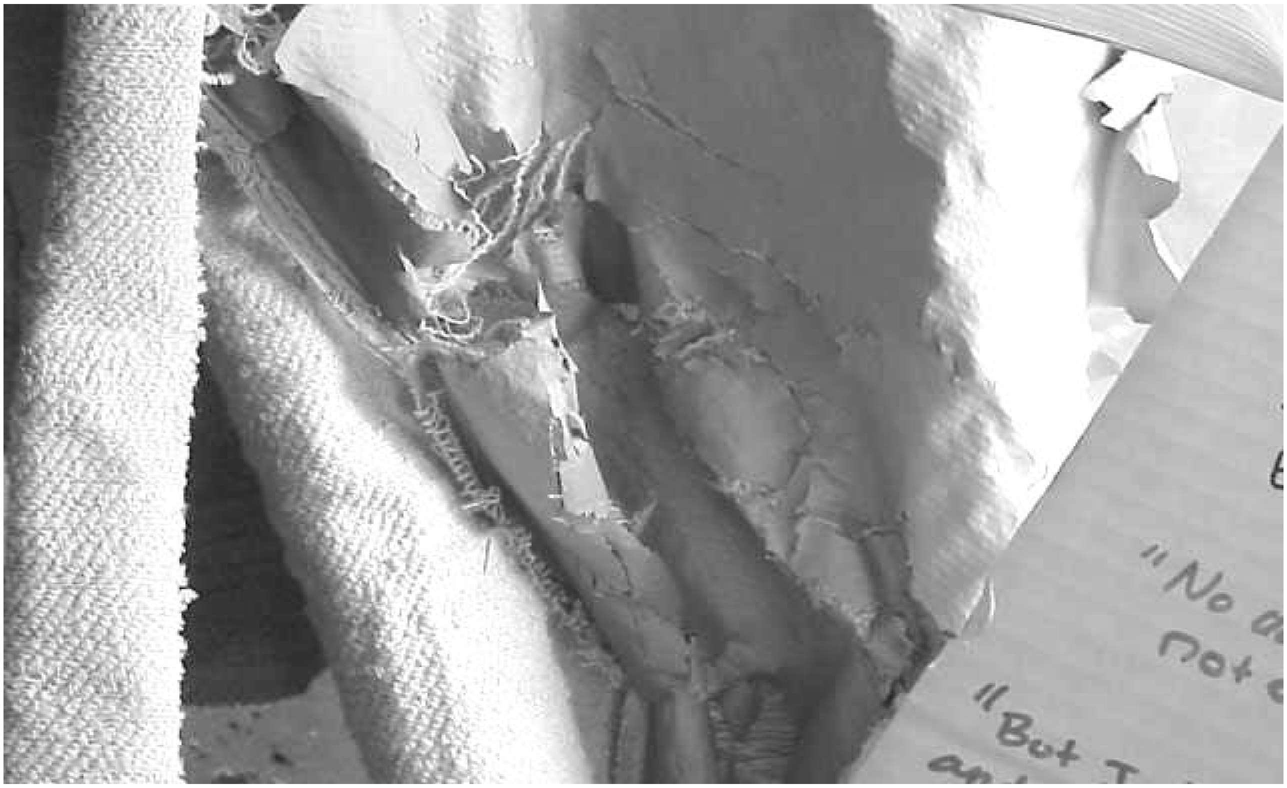
Picture 11

Water Damaged Book in Library, Dark Spots Indicate Mold Growth

Picture 12

Water Damaged Curtains in Classroom

Picture 13



Condition of Water Damaged Classroom Curtains

Picture 14

Water Damaged Ceiling Tiles Dark Spots Indicate Potential Mold Growth

Picture 15

Flowering Plants on top of Univents

Picture 16

Pooling Water and Ice on Rooftop

Picture 17

Paints, Waterproofing and Other Materials Stored in Room 151 Storeroom

Picture 18

Accumulated Chalk Dust in Classroom

Picture 19

Missing Ceiling Tiles

Picture 20

Dirt/dust Accumulation in Grill of Portable Classroom AC

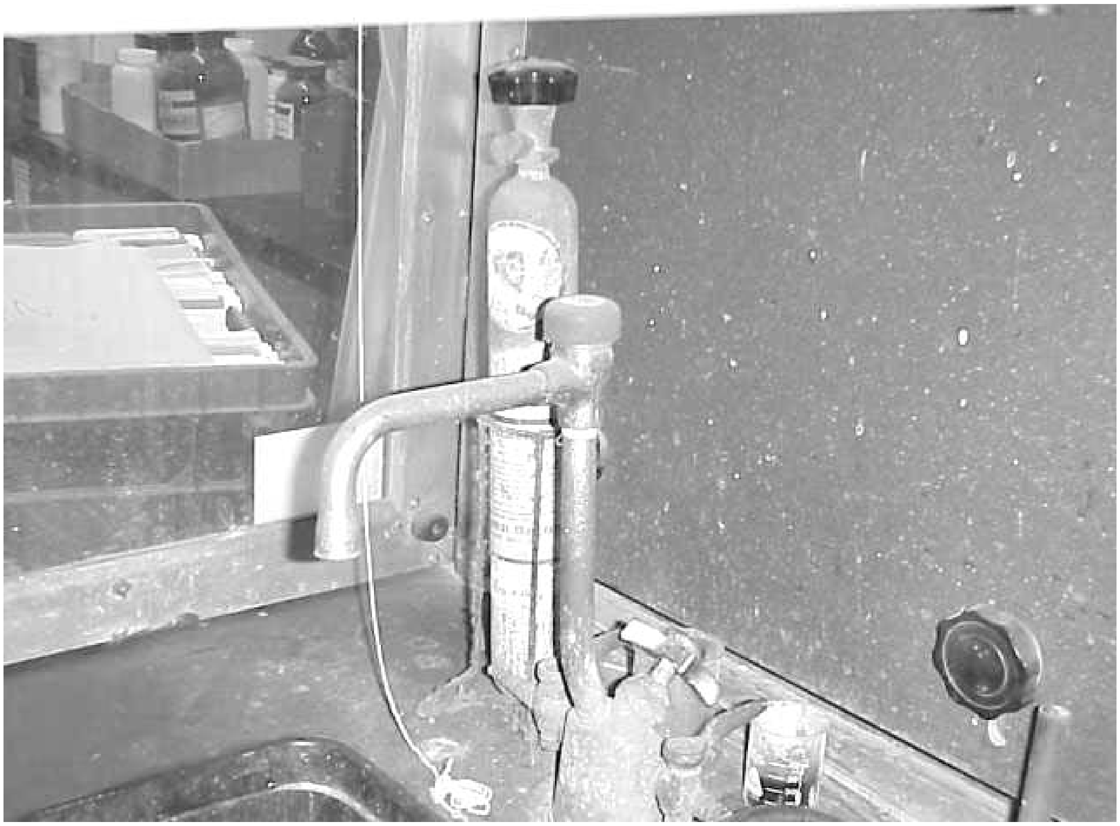
Picture 21

Gas Cylinders in Chemical Storeroom Secured with Tape

Picture 22

Gas Cylinders in Chemical Storeroom Secured with Tape

Picture 23



Chlorine Gas Cylinder Located in Inoperable Vent Hood
Note Corrosion of Metal Fixtures

TABLE 1

Indoor Air Test Results – Holliston High School, Holliston, MA – December 22, 2000

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	330	32	30					Weather conditions: clear/cold
Chemical Storeroom	980	68	29	0	No		Yes	
157	974	69	25	29	No	Yes	Yes	Ceiling mounted univent
169 (Lab)	1334	70	30	24	No	Yes	Yes	No seal around door separating renovation area from room, exhaust blocked, unused terrariums, ceiling mounted univents
167	1184	70	29	4	No	Yes	Yes	2 Ceiling mounted univents-1 off, chemical hood inoperable-chemicals stored inside (chlorine), univent access stripped-BEHA staff unable to open to observe filters
Science Prep Room	1323	73	29	3	No	No	Yes	Exhaust off (timer), hole in CT
159	1354	71	27	17	No	Yes	Yes	2 univents-1 off, 2 exhaust vents-blocked by cart, door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 2

Indoor Air Test Results – Holliston High School, Holliston, MA – December 22, 2000

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation Intake	Ventilation Exhaust	Remarks
153	845	73	25	13	No	Yes	Yes	Door open, missing CT
151	750	71	22	9	No	Yes	Yes	Exhaust blocked
Storeroom								Paint & waterproofing storage, flammables
208	1209	73	27	2	Yes	Yes	Yes	Air intake for univent on roof, exhaust vent partially obstructed, 2 water damaged CT
204	1410	73	24	21	Yes	Yes	Yes	Deteriorating curtains, 6 plants-2 on univent, exhaust blocked by file cabinet
202	1594	73	26	22	Yes	Yes	Yes	Exhaust blocked by bookcase, 7 plants-flowering plants on univent, boxes on univent
203	1320	69	26	22	Yes	Yes	Yes	Univent diffuser covered with books, window mounted a/c-cover missing-accumulated dust/dirt, door open
201	1224	70	24	15	Yes	Yes	Yes	Unit exhaust ventilator-weak draw, door open

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 3

Indoor Air Test Results – Holliston High School, Holliston, MA – December 22, 2000

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
200	1042	69	24	13	Yes	Yes	Yes	Unit exhaust ventilator-off, items on univent, door open
211	1161	71	24	11	Yes	Yes	Yes	Unit exhaust ventilator-off, items on univent, chalk dust
210	1971	73	29	24	Yes	Yes	Yes	Univent off
English Office	1443	75	26	5	Yes	No	No	Photocopier
Math Office	1120	76	25	1	Yes	No	No	
209	1194	76	22	20	Yes	Yes	Yes	
206	1600	75	24	15	Yes	Yes	Yes	Univent off, exhaust blocked by file cabinet, door open
207	1087	75	21	15	Yes	Yes	Yes	Boxes on univent
205	1651	74	24	15	Yes	Yes	Yes	Univent diffuser blocked by items
101	1236	72	24	20	Yes	Yes	Yes	Univent diffuser blocked by items, exhaust off
100	2956	75	33	13	No	Yes	Yes	Passive door vent, exhaust vent off

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

TABLE 4

Indoor Air Test Results – Holliston High School, Holliston, MA – December 22, 2000

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
104	1810	75	27	22	No	Yes	Yes	Ceiling mounted univent-off, exhaust vent blocked by file cabinet, missing CT, chalk dust, door open
103	707	74	20	4	Yes	Yes	Yes	Chalk dust, door open
Business Department	1000	72	23	2	Yes	No	No	Photocopier, door open
Library	816	72	22	~15	Yes	Yes	Yes	Book mold
Gliga Room	780	72	23	2	No	Yes	Yes	Passive supply, door open
Health Room – Gym Area	1030	65	29	19	Yes	Yes	No	3 water damaged CT

*** ppm = parts per million parts of air**
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred
	600 - 800 ppm = acceptable
	> 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%